Harnessing Energy from Chemical Wastewater for Sustainable Electrical Generation through Steam Turbine.

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Abstract - The present study suggests the new capability of power production through steam turbines using the chemical wastewater as a feedstock. As a case of development of a line of energy recovery technologies (e.g.: anaerobic digestion, waste heat recovery and production of chemical energy for thermal energy), the present study discusses their integration with the steam turbine technology. This is in terms of technical and environmental sustainability for energy production

Key Words: Chemical Wastewater, Energy Recovery, Steam Turbine, Sustainable Energy, Waste Heat Utilization, Power Generation, Industrial Waste Management, Thermal Energy Conversion.

1.INTRODUCTION *(Size 11, Times New roman)*

Wastewater produced in the chemical industry during manufacture is referred to as chemical industrial wastewater. In majority of the cases, effluent is a mixture of diverse contaminants of comparable density and consists mainly of organic matter, heavy metals and other hazardous chemicals with environmental and health risks. Technologies for treatment and disposal should therefore be made appropriately to remove such risks. Physical, chemical and biological sewage treatment has been conventionally used. But manufacturing techniques used may be energy-demanding, expensive, and resource-intensive with negative effects on the environment.Other technologies for energy recovery from treated wastewater, such as anaerobic digestion, waste heat recovery and bioelectrochemical systems, have been investigated in recent years [1, 2, 35]. The scope of the current paper is to investigate the feasibility of electrical power generation by steam turbine from chemical wastewater as a green energy. We shall discuss anaerobic digestion, chemical process heat recovery, and other power generation processes using steam turbines to generate green energy.

I. WASTEWATER TREATMENT AND POWER GENERATION

A. *Production of Biogas using the Anaerobic Digestion Process*

Anaerobic digestion is an anaerobic microbial process of the readily available organic waste materials available in wastewater to convert into biogas under zero air supply. Biogas can be utilized for heat as it is combusted or can be upgraded to electricity. A few independent parameters play an important role in effective biogas production such as pH and temperature and retention time are quite crucial in the effective operation of the anaerobic digestion process [1].

Table 1: Principal Parameters for Anaerobic Digestion

Parameter	Optimal Range
Temperature	**30-60 °C**
pH	**6.5–7.5**
Retention Time	**15–30 days**

Anaerobic digestion gives rise to a biogas that is employed to generate heat or steam for recovery from wastewater.

B. *Heat recovery from chemical processes*

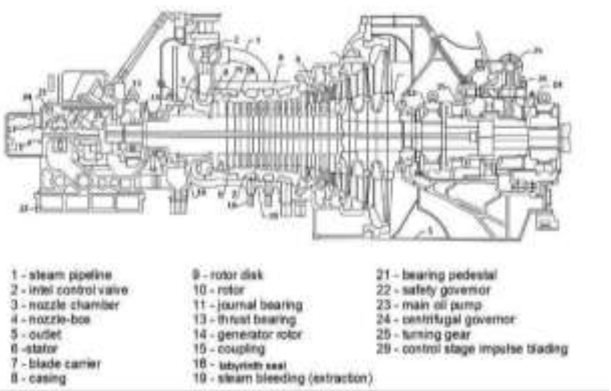
Industrial waste heat is generally larger than the energy generated. Waste heat can be recovered by heat exchangers or other heat recovery devices and heat is utilized to generate steam. Condensed steam can be utilized to power a steam turbine for generating electricity. Chemical reaction from wastewater, i.e., chemical oxidation, such use is applied "Heat energy generated by chemical reactions in waste water" [2].

II. STEAM TURBINE TECHNOLOGY

A. *Fundamentals of Steam Turbine*

Steam turbines are founded on the principle of use of steam thermal energy to generate mechanical energy. The steam pushes on the blades when it flows over them in a manner such that they turn and make the turbine turn. The steam turbines include impulse turbines and reaction turbines. Efficiency of steam turbines can be enhanced by waste heat recovered during steam production [3].

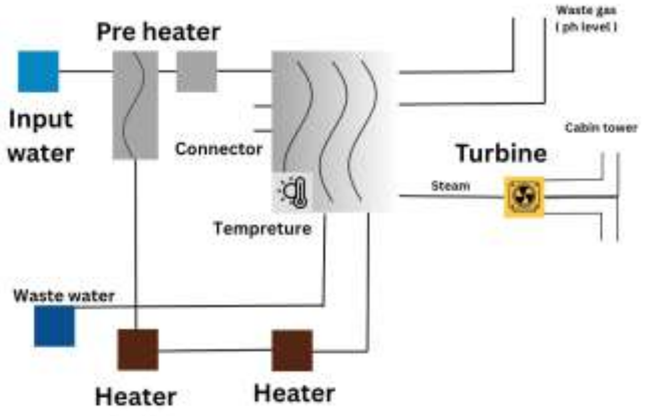
B. *Figures: Steam Turbine*



C. *Inlet with WWTPs*

Application of sewage plants to drive steam turbines makes feasible the generation of electricity through combustion of sewage thermal energy. Effluent wastewater-treatment is an energy feasible source. It is not yet commercially viable technology but a frontrunner solution in wastewater energy recovery from infrastructure [4].

D. *Figures: Line Diagram of Steam Turbine*



III. SUSTAINABILITY AND ECOLOGICAL ASPECTS

A. *Mitigation and Environmental Impacts*

Wastewater has the ability to decrease our dependency on conventional fossil fuels and decrease green house emissions. Green house gas emissions of wastewater treatment can be decreased to a large degree by reusing waste heat and biogas. This is achieved in regenerative economics where investment and return on energy is optimized to the best possible extent to cause the least damage to the environment to the largest extent with the best utilization of resources [5].

B. *Cases and Success Stories*

There have been several case studies that have shown the potential of retrofitting energy recovery technology in WWTPs [6]. Examples show the possibility of fit-out of energy recovery systems in existing old facilities in an attempt to reap environmentally (i.e., sustainability) and operationally (i.e., efficiency) gains.

IV. LIMITATIONS AND CONSTRAINTS

A. *Cost Feasibility*

The cost of installation of the financial and operating category of steam turbines and associated waste heat recovery systems is staggering. It also possesses an even more daunting return on investment (ROI). It takes a couple of years depending on the system complexity and energy recovery [7].

B. *Technical Challenges*

Uncertainty in wastewater discharge is one of the major technical issues, hindering continuous production of steam. Energy recovery from certain of the chemical effluents has also not been a research topic for a long time, and more study needs to be conducted to render water recovery economical [9]. Demonstration of the above technologies, especially in the high-capacity plants that inject humongous amounts of water, is of utmost importance.

V. FUTURE RESEARCH DIRECTIONS

A. *Increased Efficiency of Waste Heat Steam Turbine*

The majority of the future activities would also consist of the development phase of steam turbines, specifically on low-temperature steam turbines. Hybridization of the steam turbines with other systems like fuel cells and heat pumps to provide hybrid systems is one of the methods that will produce improved % CSP penetration in transport [10].

B. *Smart System Development*

Smooth functionality of an intelligent wastewater energy recovery system would be the significant benefit in increasing productivity. There are also possibilities where real-time monitoring by means of automation and intelligent sensors through machine learning or artificial intelligence can optimize energy reclamation from wastewater materials [11].

C. *Energy Reuse from Other Wastewaters*

There is a need for further research on tapping energy recovery from other sources of wastewater, i.e., agricultural or household washing, to apply the technology in larger areas [12].

CONCLUSION

The electrical energy can be derived from chemical wastewater to a considerable extent. Through use of anaerobic digestion and utilization of waste heat and the technology of the steam turbine, an independent system where the wastewater would be treated and electricity would be produced would be established. This has the capability to cut down on the use of fossil fuels, lower greenhouse gas, and improve energy efficiency in sewage treatment plants. Commercialization and innovation of the technologies, and additional investment and challenges. There will be additional work which will enhance and extend the above technology further and bring the technology into practicality in terms of scalability as well as feasibility by further improving the efficiency of steam turbines in energy, systems integration, and intelligent systems [13].

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